Hybrid Electric Vehicles—Electric Drive System Components and Vehicle Accessories

In order for HEVs to attain the performance, economy, comfort, and convenience levels necessary to win widespread consumer acceptance, highly efficient and economical electric drive systems and vehicle accessories need to be developed. Some of the components of these systems have no counterpart in conventional vehicles, so new systems and control strategies need to be created which take into account everything from system integration and cost to the development of a maintenance infrastructure.

Motors

Motors are the "work horses" of an HEV drive system. In an HEV, an electric traction motor converts electrical energy from the energy storage unit to mechanical energy that drives the wheels of the vehicle. Unlike a traditional vehicle, where the engine must "ramp up" before full torque can be provided, an electric motor provides full torque at low speeds. This characteristic gives the vehicle excellent "off the line" acceleration.

Important characteristics of an HEV motor include good drive control and fault tolerance, as well as low noise and high efficiency. Other characteristics include flexibility in relation to voltage fluctuations and, of course, acceptable mass production costs.

Front-running motor technologies for HEV applications include the permanent magnet, AC induction, and switched reluctance motors. These, as well as several other types of motors, are being evaluated in current HEV-related programs.

Regenerative braking

One of the most important differences between an HEV and a traditional vehicle is the former's ability to reclaim a portion of the energy otherwise lost to braking. In an HEV, when the driver brakes, the motor becomes a generator, using the kinetic energy of the vehicle to generate electricity which can stored in the battery for later use. Traditional friction brakes are necessary, as well as a consistent strategy to blend the two braking mechanisms smoothly. Regenerative and friction brakes need to be controlled electronically so that stopping ability is maximized while dual brake operation is made transparent to the operator.

Power electronics and controllers

With the evolution of such advanced features as anti-lock brakes, air bags, and computerized engine controls, the conventional automobile has become more and more dependent on sophisticated electronics over the past several years. This trend will be accelerated in HEVs, which in addition to the other features, rely heavily on electronic controllers to distribute the proper amount and type of power into and out of the appropriate sub-system at the appropriate time.

The power electronics portion of the electric drive system is the "brains" of an HEV. Because of its increasing complexity, HEVs require faster, more complex sensing and control devices with a greater number of input/output channels. Since the power supplied by the battery is DC, it must be converted to the AC required

by the motor by an electronic power inverter, which determines the exact nature and timing of the current and voltage waveforms. Custom devices, including application-specific integrated circuits, mixed analog/digital devices, and smart power devices are required. High power density, low-loss capacitors, and inductors are also needed for high speed switching applications. HEVs also need several 1-100 kw power supplies for air conditioning, power steering, power brakes, propulsion motor operation, and other vehicle functions.

All of these electronic operations and more must be managed with excellent reliability, while adding minimal weight and cost to HEV production. The key to achieving this is a device called a Power Electronic Building Block (PEBB) which integrates many of the controls, power components, drivers, and bus work of the power electronics system into a single package. PEBBs will reduce the cost and improve the reliability and efficiency of the power system beyond current technology. Currently, DOE is involved in R&D efforts with the Department of Defense to develop higher efficiency, low-cost designs. Issues impacting PEBB integration into production HEVs include cost, size, increased switching speed, and better temperature tolerance. Ford, Chrysler and General Motors, in their capacity as partners in the overall HEV Program, provide technical specifications and maintain a two-way dialog with PEBB researchers.

Vehicle accessories

While often non-essential to actual vehicle operation, "hotel features" such as heating, cooling, power steering, and lights are obviously essential in any vehicle seeking to gain consumer acceptance. Many of these systems need to be designed differently in HEVs than they are in conventional automobiles because their operation is interrelated with systems that work differently in HEVs.

For example, in a conventional vehicle, the climate control system operates "piggy-back" on the engine. Since the engine is not always in operation in an HEV, a new system and control strategy needs to be developed in order to provide passenger comfort at all times.

Another example is power steering, which is enabled in a conventional vehicle by a continuously-operating hydraulic pump driven by the engine. With HEV's non-continuous engine operation, a new, consistent power steering control strategy needs to be developed. Front-runner technologies include electric and electro-hydraulic power steering.

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